MOTOROLA

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February 22, 1996

Mr. William F. Caton
Acting Secretary
Federal Communications Commission
1919 M Street, N.W.
Room 222
Washington, D.C. 20554

RE: CC Docket No. 92-297

Dear Mr. Caton:

This letter will serve to amplify and clarify Motorola's position with respect to the various band plan options under consideration in the above-referenced proceeding. As explained below, while Motorola is willing to be flexible and accept certain limitations on the spectrum in which it is licensed to operate in the U.S., it cannot agree to any band plan under which LMDS transmissions would threaten the successful launch, deployment and operation of the IRIDIUM® System constellation or which would degrade the IRIDIUM System's feeder link availability beyond reasonable and acceptable telephony standards. Thus, Motorola urges the Commission to adopt either Option 1 (the band plan proposed in the Third Notice of Proposed Rulemaking) or Option 3, with the modification that the IRIDIUM System must be allowed to access the entire 29.1-29.3 GHz band.

At the status conference convened by Commission staff on February 16, 1996, the staff explained that it had recommended that the Commission adopt a band plan identified as Option 4. While Option 4 provides Motorola with 100 MHz of spectrum that would not be shared with LMDS, it would require sharing with LMDS subscriber-to-hub links in the remaining 100 MHz to which Motorola needs access, under the sharing rules advocated by the LMDS interests. While Motorola is willing to make compromises, the limitations posed by Option 4 go beyond what we can accept both in terms of the amount of and terms of access to feeder link spectrum.

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Specifically, option 4 reduces the amount of usable spectrum that would be available to Motorola by 50% and would require that the single most critical feeder link channel on the IRIDIUM System share spectrum with LMDS return links under conditions that would result in unacceptable interference to that channel.[1] This particular feeder link channel, which has its center frequency at 29.2298 GHz (the center frequency of the paired downlink is at 19.5073 GHz), is the only omnidirectional link used by the satellites and, therefore, it is the only means of communicating with the spacecraft during launch and early orbit (i.e., when attitude control is not stabilized), deorbit, and those times when a satellite may be tumbling out of control. As the communications link of last resort, the availability of this channel at all times could easily be the difference between saving and losing a particular satellite and is essential to the successful launch, deployment and operation of the IRIDIUM System constellation.

When receiving signals on this omnidirectional link, the field of view of the satellite will be from horizon to horizon and, therefore, the satellite will receive interference on this channel from any location within its view. Consequently, this link is susceptible to interference from a much larger number of LMDS transmissions than the standard IRIDIUM System feeder links. The net effect is that a terrestrial interferor can impact communications between a TT&C (i.e., telemetry, tracking and control) site and a spacecraft even when the interferor is located thousands of miles away from the TT&C sites.[2]

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[1]	The type of rules that would be necessary to enable Motorola to share spectrum with LMDS return links are contained in a letter dated November 27, 1995, from Bary Bertiger, Corporate Vice President and General Manager, Motorola Satellite Communications Division, to Thomas Tycz, Chief, Satellite and Radio Communication Division, FCC. The rules advanced by LMDS interests are are less conducive to sharing than even the FCC staff's proposed rules as presented at the January 25 status conference.

[2]	Motorola also notes that Sharing Principle 1(d) associated with Option 4 is inconsistent with the agreement Motorola reached with LMDS interests during the 28 GHz negotiated rulemaking in terms of the number of IRIDIUM System feeder link stations that may be deployed in the United States. This can be corrected by increasing the number of such feeder link stations identified in Principle 1(d) from six to eight.

With regard to the other band plan options which have been under consideration in recent weeks, Motorola stated at the February 5 status conference, and in correspondence to Mr. Thomas Tycz dated February 6, that Option 2 (as outlined by Commission staff at the January 25, 1996 status conference) and Option 2A (as proposed by Hughes Communications at the February 5 meeting) were totally unacceptable to Motorola because sharing between the IRIDIUM System feeder links and LMDS return links (subscriber-to-hub) under the conditions proposed by the LMDS proponents, and even under those proposed by Commission staff, would degrade the IRIDIUM System's feeder link availability beyond reasonable and acceptable telephony standards.[3] Motorola also indicated at the February 5 meeting its willingness to accept the Commission's staff Options 1 and 3.[4] With respect to Option 3, Motorola indicated that although it continues to have concerns about that plan inasmuch as it reduces our stated spectrum requirements by 25 percent, it would be willing to accept that plan, with a slight modification, in the spirit of compromise and in the interest of resolving this proceeding expeditiously.[5]

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[3] Motorola's concerns about the impact of LMDS interference on IRIDIUM System performance were summarized in a paper previously submitted in this proceeding, a copy of which is attached. Motorola also elaborated on some of its concerns about sharing LMDS return links in its February 6 letter to Mr. Tycz.
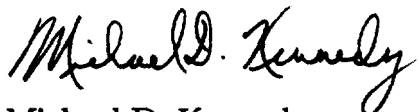
[4] Motorola also noted that, at least insofar as the band segments of immediate interest to it were concerned (i.e., 29.1-29.3/19.4-19.6 GHz), Option 2B as proposed by Hughes would meet Motorola's needs. Motorola understands, however, that Option 2B does not appear to be acceptable to either Teledesic or the LMDS community.

[5] Motorola's concerns about Option 3 could be addressed by modifying it so that that the IRIDIUM System is allowed to access the 29.25-29.3 GHz band on a coordinated basis with Odyssey feeder link stations and with GSO/FSS systems operating in this band segment. As Motorola has previously stated, its use of that band segment would be in connection with certain system command and control functions and, thus, would be only occasional. It is also essential that Motorola be authorized to construct over the full 200 MHz in each direction because of our need to coordinate frequencies outside the U.S.

Please call me should you have any questions about our position on these matters.

Respectfully submitted,

Michael D. Kennedy
Vice President and Director,
Regulatory Relations

Attachment

cc: Chairman Reed E. Hundt
        Commissioner James H. Quello
        Commissioner Andrew C. Barrett
        Commissioner Susan Ness
        Commissioner Rachelle Chong
        Ms. Michelle Farquhar
        Ms. Jennifer Gilsenan
        Mr. Donald Gips
        Mr. Scott Blake Harris
        Mr. Robert James
        Mr. Karl Kensinger
        Ms. Susan Magnotti
        Dr. Michael Marcus
        Mr. Harry Ng
        Dr. Robert Pepper
        Mr. Gregory Rosston
        Mr. Thomas Tycz
        Mr. David Wye

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Impact of Terrestrial LMDS Interference
on IRIDIUM® System Performance

Summary Conclusions

As interference into the Space Vehicle (SV) uplink reciever increses there is a resulting loss of uplink performance to an IRIDIUM® Gateway. The loss in performance results from a loss of power that can be applied to overcome rain fades. As interference increases the effective noise floor of the uplink receiver will require more signal power to close the communications link with the same quality. This added power is no longer available to overcome rain fades. Hence, any increase in interference decreases the availability of the uplink.

The atmoshperic fade allowance that is currently used is a 30 dB margin at a 10 degree elevation angle. The margin is smaller for lower elevation angles and larger for higher elevation angles because of the change in the distance between the LEO (low earth orbit) satellite and the Gateway (ground station) site. This margin must cover rain fades, atmospheric attenuation, cloud attenuation, and scintillation effects. All of these sources of signal fading are statistical in nature. Several Gateways which are installed will need to use use two channels simultaneously. The fade margin allocation for these Gateway sites is about 4 dB lower than the fade allocation for a single channel Gateway. This will lower the available margin and increase the difficulty in selecting a site that provides the needed availability.

As and example we assume that we are operating a single channel Gateway in the Atlanta, GA area. The system assumptions used are given in the analysis section below. The results are plotted in Figure 1. The figure illustrates outage estimates using no diversity and using diversity. The outage level at a total Io/No of -10 dB is about 0.33% for no diversity and about 0.12% for diversity. The resulting 11 hours per year of outage for the diversity site is within the needed range for a Telecommunications system of reasonable quality. The outage using a single site is well above what is acceptable.

For total interference levels of 0 dB Io/No and 10 dB Io/No the outage increases by about 40% and 200% respectively. In general the interference is expected to be produced at a number of sites that are not co-located with the GW site. Since they are not at the same site the interference sources will not be significantly attenuated by the rain cell that is attenuating the signal from the GW uplink transmitter. The increases in outage due to increased interference would degrade system performance and represent an unacceptable situation. This impact assessment assumes that the power control loop used in the desired communications link has time to compensate for the increased interference levels. If the interference increases quickly the outage events would increase dramatically.

For a total interference level of 20 dB Io/No the system fails to operate at lower elevation angles. This will result in predictable link failures and represents highly unacceptable communications system performance.

Analysis

The analysis presented here assumes that we have a Gateway located in the Atlanta area. The general Crane rain attenuation model [Crane, 1980] is used to estimate the rain attenuation for a single site. The point rain rate distribution tables have been updated to reflect those presented in the NASA propagation handbook [Ippolito, 1989]. The combination of algorithm and tables has been called the "Global Model" in the handbook and in CCIR literature. The earth station latitude is assumed to be 33.73 degrees North and the height is assumed to be 0.3 km. The rain region taken from Ippolito's maps (or Crane's) is the "D3" region. A frequency of 29.3 GHz is used.

The current IRIDIUM® link budget allows for a 30 dB loss due to all atmospheric attenuation sources. There are several different practices in accounting for the different attenuation sources. We will assume that rain events are not correlated with scintillation events and combine rain attenuation and scintillation via a RSS combination (per CCIR Report 564-4, section 2.5.3). The cloud and attenuation due to humidity can be significant at low elevation angles. The occurrence of clouds and humidity correlate with rain events. We will assume that these add and will use an 80% humidity estimate for rain attenuation. Scintillation loss will be computed for a 0.5% outage probability using CCIR Report 564-4 [CCIR, 1990]. Atmospheric and cloud attenuation estimates are generated using CCIR Recommendations 676 and 840.

A summary of the atmospheric attenuations are listed for low elevation angles (and 40 degrees) in Table 1. A summary of the available power allocation to overcome rain fades is summarized in Table 2. The available power allocation is computed based on the available transmitter power, the change in range as a satellite comes closer to the Gateway site, and the estimated atmospheric attenuations.

As interference levels increase the available power allocation to compensate for rain losses decreases. The interference power can be considered to be a constant spectral power level across the space vehicle receiver bandwidth (of just over 3.125 MHz). We can characterize the interference power level in terms of the ratio of interference power level compared to the receiver noise level (Io/No). This ratio is logically equivalent to the ratio of the change in effective receiver noise temperature to the effective receiver noise level. This is most often referred to as the "delta-T/T" ratio. Delta-T/T is usually written in terms of percent and an allocation of 5% for one interference source (a system) and 10% for all interference sources is typical. The Io/No is usually written in terms of decibel and the corresponding levels are -13 dB and -10 dB respectively. The effective loss in power resulting from the interference is (approximately):

$$Loss = (Io + No) / No$$

or

$$Loss = 1 + Io/No$$

where Io/No is a fraction with the power spectral densities, Io and No, in any linear units (not decibel).

Using this relationship the remaining power allocation that can be used to overcome a rain attenuation event is computed. These values are given in Table 3 for the lower elevation angles and for 40 degrees. Using the Crane algorithm (the "Global Model" [Ippolito, 1989]) for the Atlanta site the availability for a Gateway using a single Earth Terminal is calculated and given in the "no diversity" columns of Table 4. The expected

outage at a Gateway site in the Atlanta area exceeds a reasonable outage for a telecommunications service. We need to use ground station site diversity to reduce the outage to acceptable levels at such sites. We assume that we have two site diversity with a baseline separation of 35 km and an average angle between the baseline and the look vector to the satellite of 45 degrees. The outage is calculated using the conservative "Hodge" model [Hodge, 1982] combined with the Global Model the availability using two site diversity is calculated and is given in Table 4 in the "diversity" columns. More liberal results in diversity gain are predicted by the Bothias model [Bothias, 1986]. The results using the Bothias model would accentuate the effect of lost signal fade allocation.

It is important to note that since the interference sources are not located at the same site as the Gateway uplink transmitter the interference sources will not be attenuated by the rain cell that is attenuating the desired uplink signal. We expect the interference sources to be distributed over a wide region. Some of the sources can be attenuated by rain but the majority of the sources will not be attenuated by the rain cells. The summed power of the interference sources will be dominated by the strong, unattenuated sources and the total interference will not be greatly reduced during rain events.

The outages shown in Table 4 are given for elevation angles between 5 and 10 degrees and for 40 degrees. The elevation angle between the satellite and the Gateway site varies continuously throughout a pass (of a satellite overhead) and the maximum elevation angle varies from pass to pass. The minimum elevation angle needed and the distribution of elevation angles vary depending on the latitude of the Gateway site and potential obstructions on the horizon of each Earth Terminal (ET) site. The Gateway must remain in continuous contact with the satellite constellation. In order to do this the incoming SV must be acquired prior to dropping the outgoing SV. An overlap in time is needed because the Gateway requires a minimum amount of time to acquire the new space vehicle. During the acquisition process the following sequential steps are needed: 1) the Earth Terminal must scan the antenna to find the SV signal; 2) the ET electronics must acquire the downlink signal; 3) the SV electronics must acquire the uplink signal; and 4) the computers must establish a logical link.

For GW sites at the latitude of the Atlanta site the outage can be approximated by using 0.25 times the outage at 8 degrees elevation angle and 0.75 times the outage at 40 degrees elevation angle. A minimum elevation angle of just below 7 degrees is needed to assure continuous contact with the constellation. The results of this weighted result are representative and are plotted in Figure 1.

The GW sites locations are carefully selected to meet several criteria including a maximum outage due to atmospheric conditions. A reasonable outage is about 0.13% of the time or about 11 hours per year. The dual diversity site meets this requirement for interference levels of -10 dB Io/No or below. As interference increases above this level the link performance is degraded. For interference levels above an Io/No of 0 dB the degradation becomes very large. At an Io/No level of 20 dB there are times when the interference alone causes link failures and the total outage is very large.

These results are based on the ability to overcome interference sources using the power control function of the IRIDIUM® Feeder link systems. This power control loop

cannot respond to a fast increase in the noise floor. A major assumption in this analysis is that the interference sources result in a distributed interference geometry where there are no quick increases in interference. For Io/No levels below 0 dB the system typically can handle quick changes in the interference level without suffering a link failure. Quick changes in the interference level above 0 dB Io/No can result in a link failure. In general quick changes should be considered those resulting in an increase in "Io+No" of more than 5-10 dB in one second.

References

[Bothias, 1986] Bothias, L., Battesti, J. and Rooryck, M, "Diversity improvement Factor - Prediction of the Improvement due to Diversity Reception on Microwave Links", Microcoll, Budapest, 1986.

[CCIR, 1990] CCIR Report 564-4, "Propagation Data and Prediction Methods Required for Earth- Space Telecommunications Systems", Section 2.2.4, "Diversity", Section 2.5.3.

[Crane, 1980] R. K. Crane, "Prediction of Attenuation by Rain," IEEE Transactions on Communications, Vol. COM-28, No. 9, September 1980.

[Hodge, 1982] D. B. Hodge, " An Improved Model for Diversity Gain on Earth-Space Propagation Paths," Radio Science, Vol. 17, No. 6, Pages 1393-1399, November-December 1982.

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Tables and Figures

Table 1 - Atmospheric Attenuations

Elevation (deg)	Oxygen (dB)	Water Vapor (dB)	Clouds (dB)	Total Atm. Attn. [dB]	Scintillation x(p) dB
5	1.20	4.59	4.59	10.38	5.59
6	1.00	3.83	3.83	8.66	4.45
7	0.86	3.28	3.28	7.43	3.67
8	0.75	2.87	2.87	6.50	3.10
9	0.67	2.56	2.56	5.79	2.68
10	0.60	2.30	2.30	5.21	2.34
40	0.16	0.62	0.62	1.41	0.41

Table 2 - Loss Allocation Available to Overcome Rain

Elevation [deg]	Range [km]	Avail. Loss [dB]	Total Atm. Attn. [dB]	Scintillation x(p) [dB]	Rain Margin for Uplink [dB]
5	2740.67	28.58	10.38	5.59	17.31
6	2650.35	28.87	8.66	4.45	19.71
7	2563.73	29.16	7.43	3.67	21.42
8	2480.75	29.44	6.50	3.10	22.73
9	2401.33	29.73	5.79	2.68	23.79
10	2325.37	30.00	5.21	2.34	24.68
40	1131.52	36.26	1.41	0.41	34.85

Table 3 - Loss Allocation Available with Interference

Io/No=	-20	-10	0	10	20
loss=	-0.043214	-0.41393	-3.0103	-10.4139	-20.0432
Elevation [deg]	*Remaining Rain Margin*				
5	17.27	16.90	14.30	6.90	-2.73
6	19.67	19.30	16.70	9.30	-0.33
7	21.38	21.00	18.41	11.00	1.38
8	22.69	22.32	19.72	12.32	2.69
9	23.75	23.38	20.78	13.38	3.75
10	24.64	24.27	21.67	14.27	4.64
40	34.81	34.44	31.84	24.44	14.81

Table 4 - Availability Verses Elevation Angle and Io/No

Elev. [deg]	No Diversity - Single Site					Diversity - Two Sites				
	Io/No -20	-10	0	10	20	-20	-10	0	10	20
5	2.56	2.61	3.07	4.95	100.00	1.30	1.37	1.80	3.90	100.00
6	1.86	1.92	2.22	3.63	100.00	0.81	0.85	1.19	2.56	100.00
7	1.48	1.52	1.75	2.82	4.95	0.58	0.61	0.83	1.87	4.86
8	1.18	1.18	1.41	2.27	4.51	0.45	0.46	0.62	1.40	4.11
9	0.96	0.99	1.15	1.89	3.93	0.35	0.36	0.46	1.09	3.34
10	0.77	0.79	0.97	1.60	3.43	0.28	0.29	0.37	0.85	2.75
40	0.07	0.07	0.08	0.12	0.27	0.02	0.02	0.02	0.04	0.10

Figure 1 - Effect of Interference on Outage

Figure 1 - Effect of Interference on Outage